Spray Nozzles Used for Chemical Injection in Environmental Applications

John W. Coulston
Lechler, Inc., 445 Kautz Rd, St. Charles, IL, 60174
E-mail johncoulston@lechlerusa.com , Telephone (1-800) 777-2926 ext 6813

Mughis Naqvi Co-author
Lechler, Inc., 445 Kautz Rd, St. Charles, IL, 60174
E-mail mughisnaqvi@lechlerusa.com , Telephone (1-800) 777-2926 ext 6817

Summary

Spray nozzles are a key element in creating a large contact surface area for reactions to take place. In contrast to a film of liquid deposited onto a packing the surface area presented by droplets can be superior. Further, direct droplet surface to gas contact eliminates the potential of decaying efficiency due to reactants remaining on the packing contact surfaces. In environmental control applications, with the presence of fly ash from the combustion of coal, the importance of a reliable and efficient process is key.

Simplicity in process design can have rewards in reliability. For example, for SCR, evaporating anhydrous or aqueous ammonia in a vessel and then feeding it into an AIG (ammonia injection grid) is well established. However, direct injection of aqueous ammonia via spray nozzles into the hot flue gas is gaining focus due to simplicity. Benefits include; no separate evaporation vessel needed, less equipment, and smaller site footprint requirements.

Nozzle designs have improved to meet evolving challenges. Larger free passages and designs with various configurations such as those with protective barrier air have evolved. Flexible operating ranges to meet required flow rate and droplet size ranges as operating conditions and boiler load changes. Improved operating procedures and controls to avoid wall wetting and consequential scale buildup.

Spray nozzle types include air atomizing and hydraulic. Air atomizing nozzles shear the liquid into droplets with a high velocity air stream using compressed air. Hydraulic Atomizing nozzle use only the liquid pressure to create a relatively high velocity sheet of liquid which is sheared into droplets by the relatively stationary adjacent air, atmosphere, or flue gas. A thin unstable film, held together by the liquid's surface tension, is broken to form droplets.

Air atomizing nozzle are capable of up to approximately 40:1 turn down ratio in terms of liquid flow rate. In most environmental applications where a constant droplet size is needed the turn down required is less than 10:1. Higher compressed air consumption results in smaller droplets for a given flow rate of liquid. This relationship is essentially independent of the nozzle capacity. So the quantity of nozzles to provide coverage within a duct cross section can be chosen without a change in the total air consumption of the nozzle array.

In contrast, hydraulic (liquid pressure only) nozzles are very dependent upon the capacity of the nozzle. Small nozzles produce small droplets. A small droplet requires a relatively high pressure and very low flow rates. Orifice size consequently must be extremely small and thus clog prone. There are hydraulic nozzles which maintain relatively constant droplet size over a 10:1 turndown range. For a given hydraulic nozzle, as inlet pressure is increased the droplet size decreases, even though flow rate increases.

Dust laden gas, fly ash in gas from coal combustion, can be very detrimental to spray performance if ash deposits on or near the exit edge of the nozzle orifice and cause larger droplets. To eliminate or minimize this potential build-up a nozzle which incorporates protection air, sometimes heated, can be very effective.

Clog resistance is an important requirement for reliable process operation. For a given capacity and droplet size air atomizing nozzles provide superior free passage. Especially with slurries, start up and shut down flow sequence is important. Check valves or solenoid valves, placed close to the nozzle should be used. External mix air atomizing nozzles are immune to the potential back flow problem since the liquid and atomizing air meet immediately after they leave the nozzle. However, internal mix nozzles tend to have a tighter droplet size spectrum.

Spraying co-current with the gas flow is ideal since it provides minimum risk of wetting and ash buildup on the nozzle. Spraying perpendicular to the gas has merit if the available distance for evaporation is extremely short. It can provide effectively a longer evaporation distance since the trajectory of the droplets follows a longer path.

The spray nozzle array should see no more than +/- 20% RMS gas velocity to expect good results. Methods exist to cure poor upstream gas distribution. CFD (computational fluid dynamics), cold flow physical modeling, and taking velocity measurement traverses can all contribute to a better understanding of the gas flow for each specific case.

Nozzle material of construction include commonly used 316SS, higher temperature 310SS, corrosion resistant alloys such as high nickel alloys, wear resistant materials such as cobalt alloys, silicon carbides, and other ceramics.

For each pollutant type there exists typical control method(s) and typical spray nozzle type(s) used for each method.
For NOx (oxidies of nitrogen) the SNCR (selective non catalytic reduction) process typically uses air atomizing lance due to their ability to provide a flexible range of operating characteristics in terms of droplet size, velocity, and flow rate. Collectively, SNCR, low NOx burners, and over-fire air can all contribute to control of NOx. Control of NOx via SCR (selective catalytic reduction) process uses either anhydrous ammonia evaporated by simple hydraulic nozzles, or aqueous ammonia evaporated by air atomizing nozzles, These nozzles are located in a vaporizer vessel and the evaporated ammonia is typically combined with dilution air and then feed into the AIG (ammonia injection grid) located in the flue gas duct upstream of the face of the catalyst. Simpler approaches eliminate the separate evaporation vessel and the AIG by inject anhydrous ammonia, or spray evaporate the aqueous ammonia directly in the flue gas duct with gas mixers at or downstream of the air atomizing nozzles. The mixed flow then enters the face of the catalyst.

SO2 is controlled by Wet FGD, Spray Dry FGD, and Dry lime injection. Wet limestone slurry FGD uses large hydraulic silicon carbide nozzle. Dry lime normally requires more lime consumption compared to the spray dry approach unless humidification is used to condition the gas for improve reaction. SO3 control via air atomizing nozzles, keeping the gas temperature favorable, for efficient reaction of the chemistry being sprayed.

Methods to control Hg and particulates include dry carbon injection, enhanced carbon injection, combined slurry with humidification /gas cooling. Capture of Hg onto the particulates by cooling the flue gas with air atomizing nozzles. Two stage wet ESPs , using hydraulic nozzles, for enhanced capture of the Hg laden particulates. Since gas temperature and humidity play important roles in this process the nozzles are a key factor.

Retrofits can be challenging such that inlet geometry of ducts, which were adequate for their original function, need to be analyzed for potential gas flow distribution improvements to allow a spray array to be efficient and reliable.